Field Geology at an Asteroid

Concepts Explored by RATS 2012 & NEEMO 16

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FESWG
(Annotated)

Traditional Field Geology

Geologists like to work in groups to discuss observations and interpretations in real-time. They are also not constrained by the use of a life support system. Autonomy is important in field work because it allows the team to change their plan on the go and respond instantly to new observations and questions.

How do we apply terrestrial field geology techniques to an Asteroid?

Field geologists are used to exploring expansive remote areas and hiking several kilometers in a day. Some field work does focus on documenting smaller features or areas in detail (part of a flow, road cut, small outcrop) . Here is a tumulus (pushed up section of crust) that is roughly the size of some of the smaller asteroids that could be explored by astronauts. How does your field plan change if this is the only feature you get to focus on during your field excursion?

How do we apply terrestrial field geology techniques to an Asteroid?

Terrestrial Field Geology traditionally involves:

1) Observations from remote sensing images
2) Traverse plans with multiple locations to visit in a day
3) Multiple science objectives
4) Multiple instruments and tools

How do we apply terrestrial field geology techniques to an Asteroid?

Field geology on an asteroid will depend on:

1) Reconnaissance information prior to arrival
2) Science objectives based on recon and ‘field’ observations
3) Identification of high priority science targets & tasks on the surface
4) Having the tools and instruments necessary to conduct field geology in microgravity

What will field geology on an asteroid be like?

We only have a few weeks total surface time of experience of doing field geology on another planetary body with humans. Apollo 11,12, & 14 had limited areas to explore near the LEM while Apollo 15-17 traveled several kilometers away from the lander in the lunar rovers.

Lunar Field Geology

What will field geology on an asteroid be like?

We have 40+ years of conducting EVAs in a microgravity environment. This includes building structures, fixing satellites, designing and using tools specifically for microgravity, troubleshooting issues on the fly, and the team work necessary to train for and perform an EVA.

Lunar Field Geology

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LEO Spacewalk

What will field geology on an asteroid be like?

If you combine the ruggedness and dirtiness of an EVA on the lunar surface with the challenges of moving and stabilizing during an EVA in microgravity then you'll have a decent idea of what an EVA at an asteroid might be like and the challenges this environment poses to a crew.

Lunar Field Geology

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LEO Spacewalk

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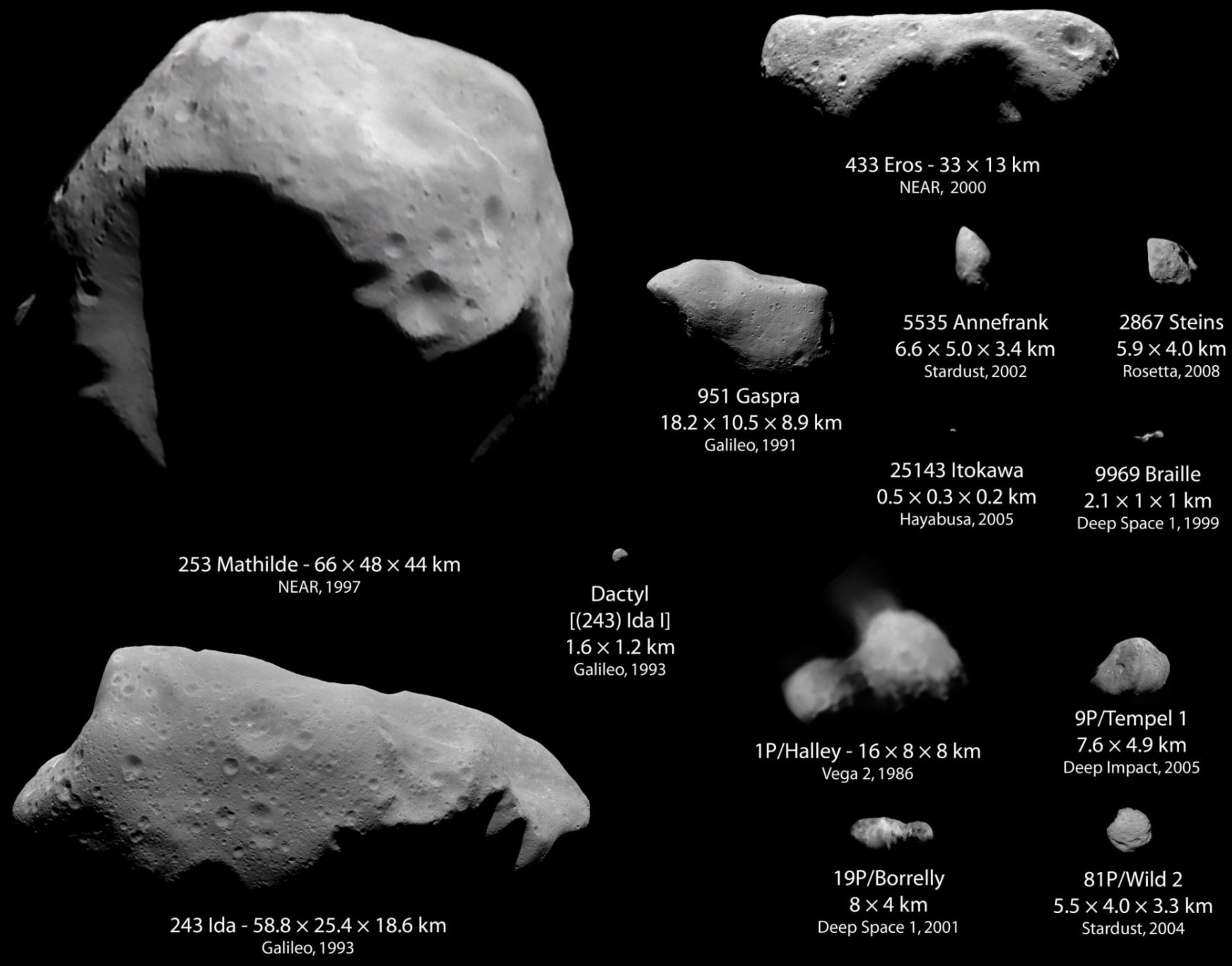
Asteroid EVA

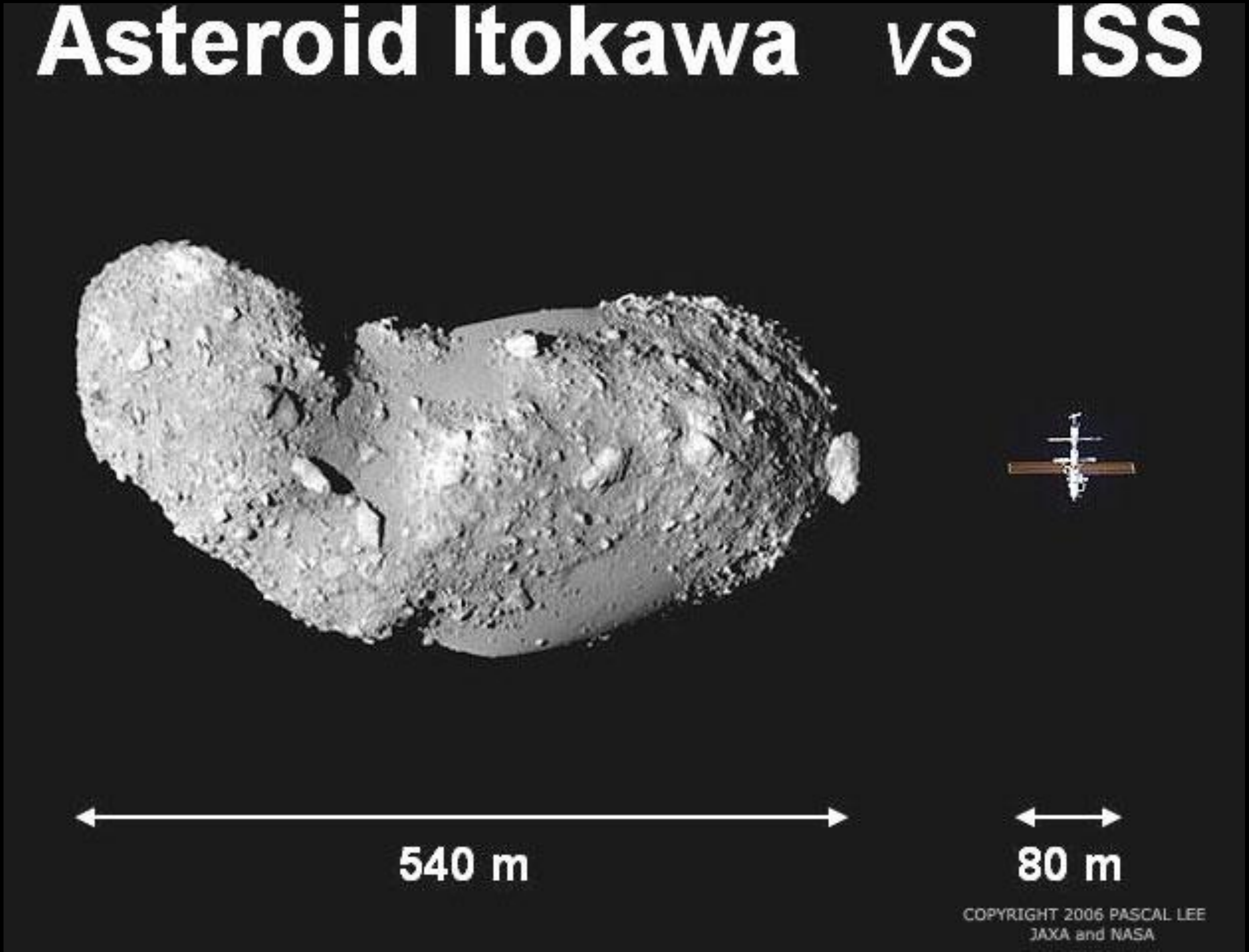
Asteroids come in all shapes and sizes

Here are a few examples of various asteroids that have been imaged. However, the asteroids pictured here are HUGE compared to the ones a crew most likely will explore.



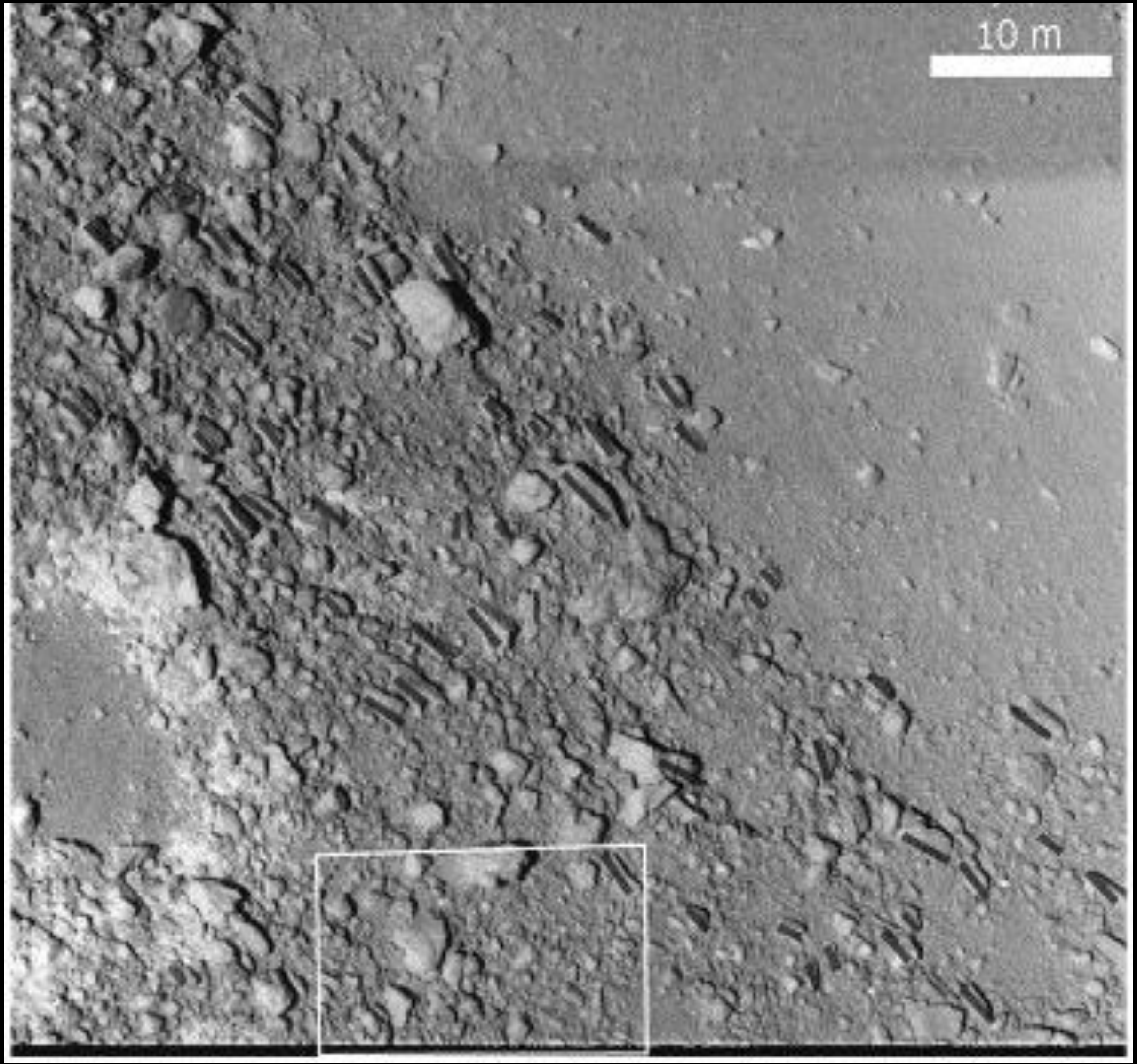
How big will these asteroids be?

Here is Itokawa (one of the smallest asteroids featured on the previous slide) compared to the ISS. Itokawa is still much larger than some of the potential asteroids for a crew mission or an asteroid capture mission. The surface of Itokawa is diverse with smooth and blocky surfaces. Some of the boulders on Itokawa's surface might be more representative in size of what a crew might visit.



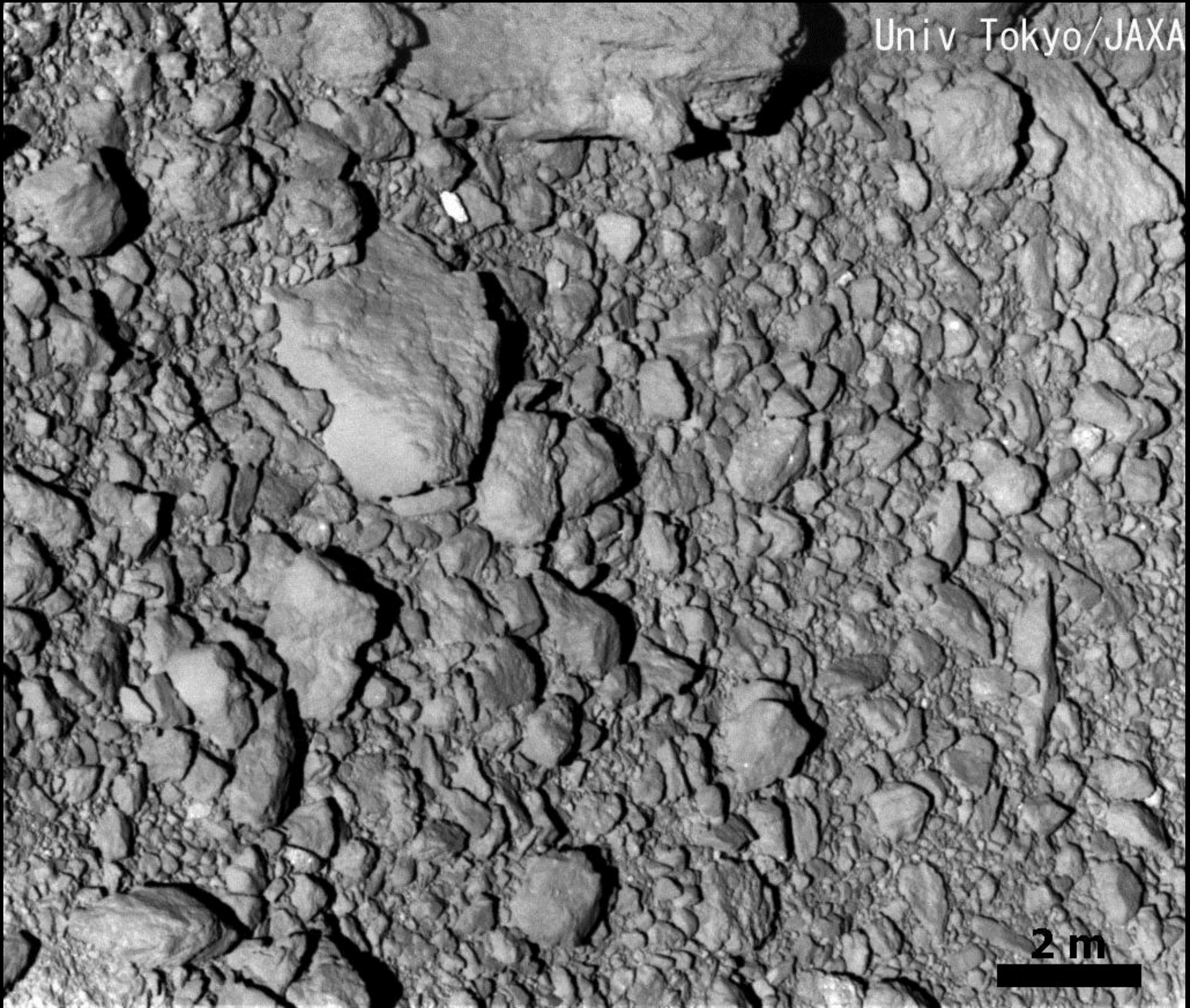
What will the surface of an asteroid be like?

When it comes to field geology, the surface can dictate the traverse plan and science objectives. Here is a boulder-rich section adjacent to a smooth section on Itokawa. One thing to think about is “How would science plans, as well as, maneuvering techniques be different for a rocky vs. a smooth asteroid?” The white box below shows the location of the image on the next slide.



What will the surface of an asteroid be like?

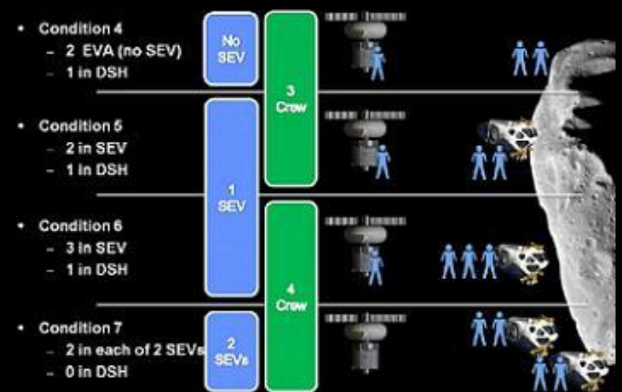
Here is a boulder-rich section on Itokawa. How would an astronaut maneuver around this site safely? How stable are the boulders on the surface? How will they react if disturbed? Could they unexpectedly shift and trap an astronaut (e.g. 127 hours)? Is there anywhere to safely anchor?



Challenges of Field Geology at an Asteroid

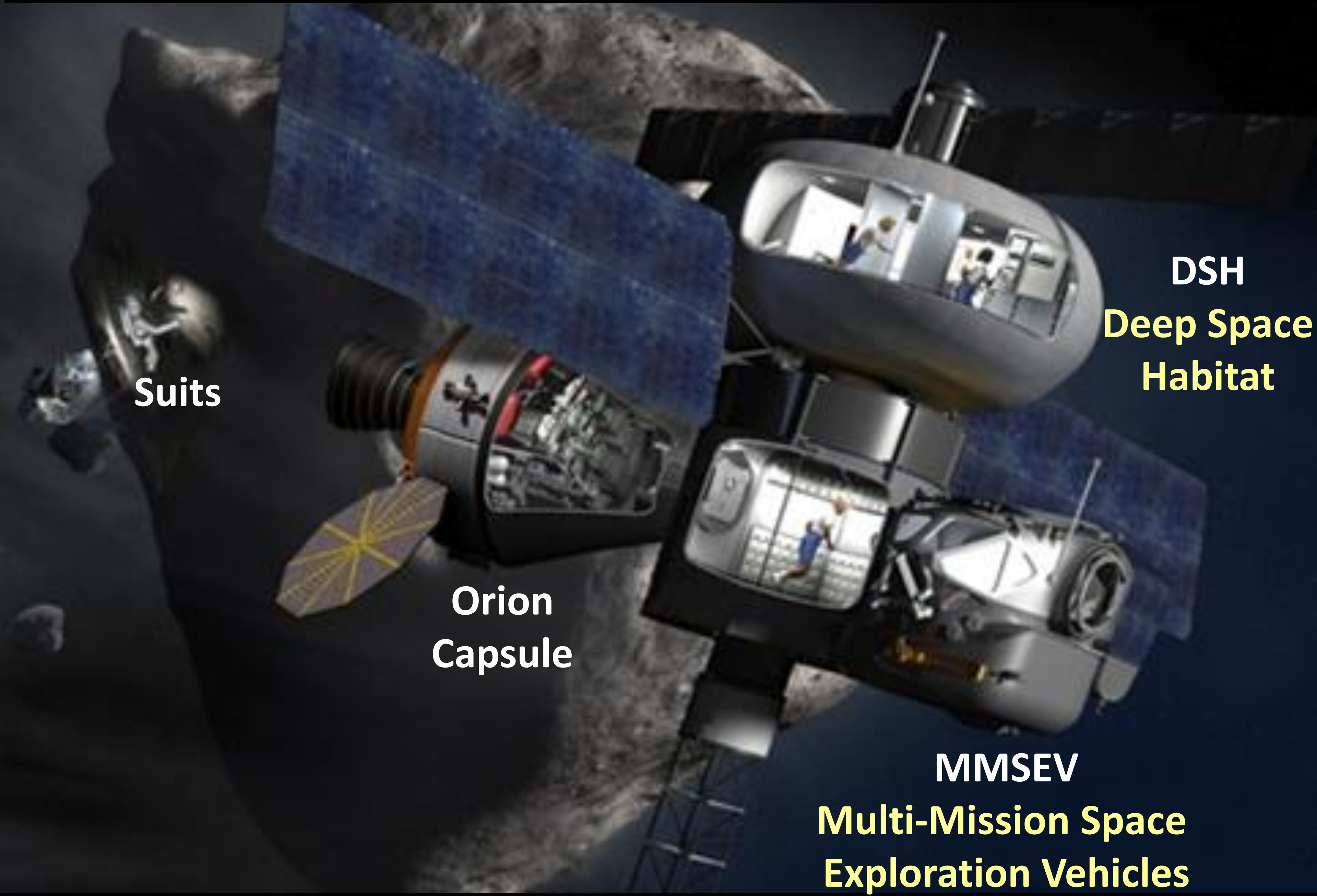
- Asteroid Characteristics
  - How big is the asteroid?
  - How does it spin?
  - What is the surface like?

- Science Operation Concepts
  - Combinations of crew and vehicles
  - Mobility
  - Stability
  - Sampling



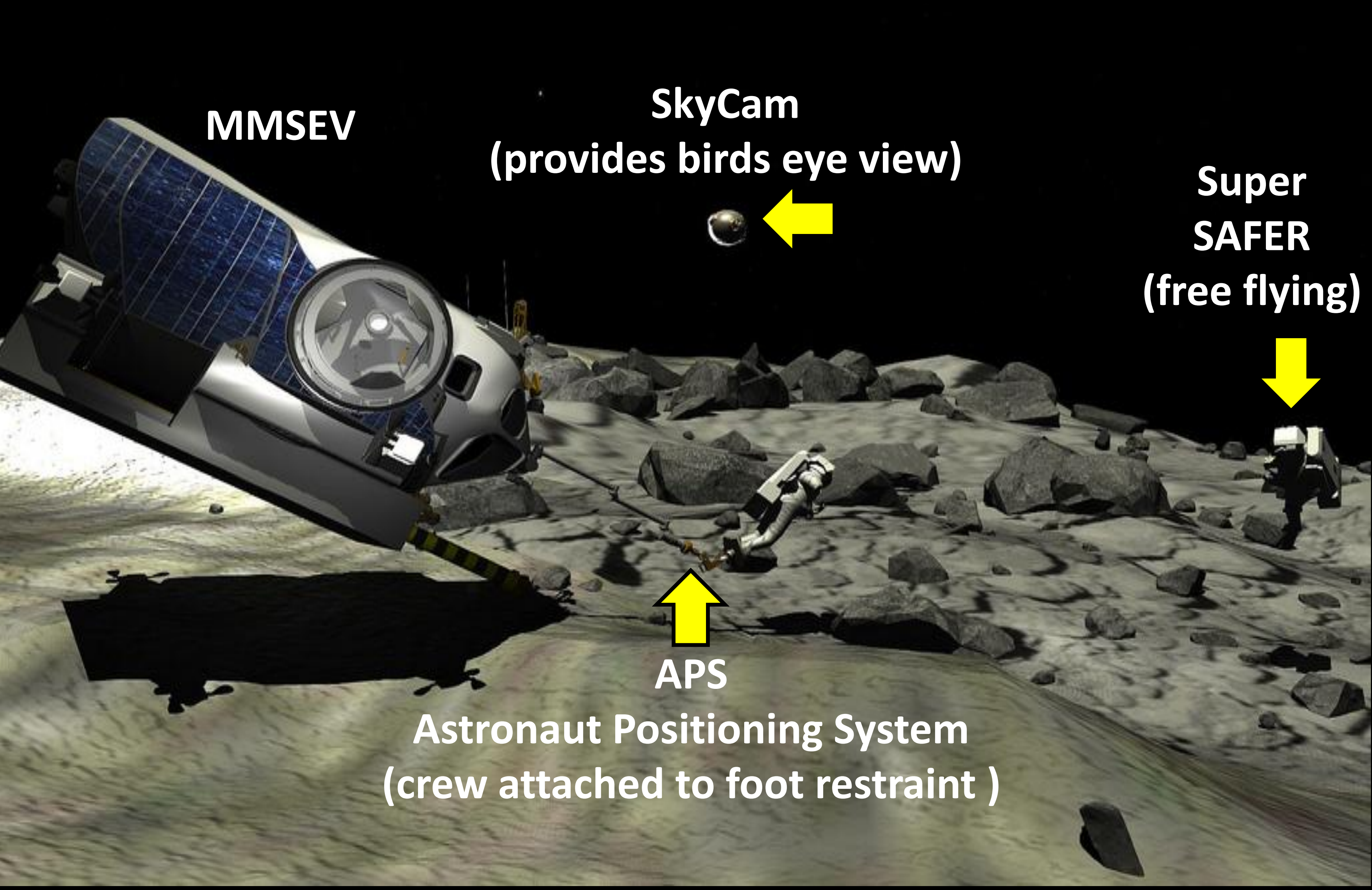
Assets in Space

Drawing of potential assets that could be used during an asteroid mission.



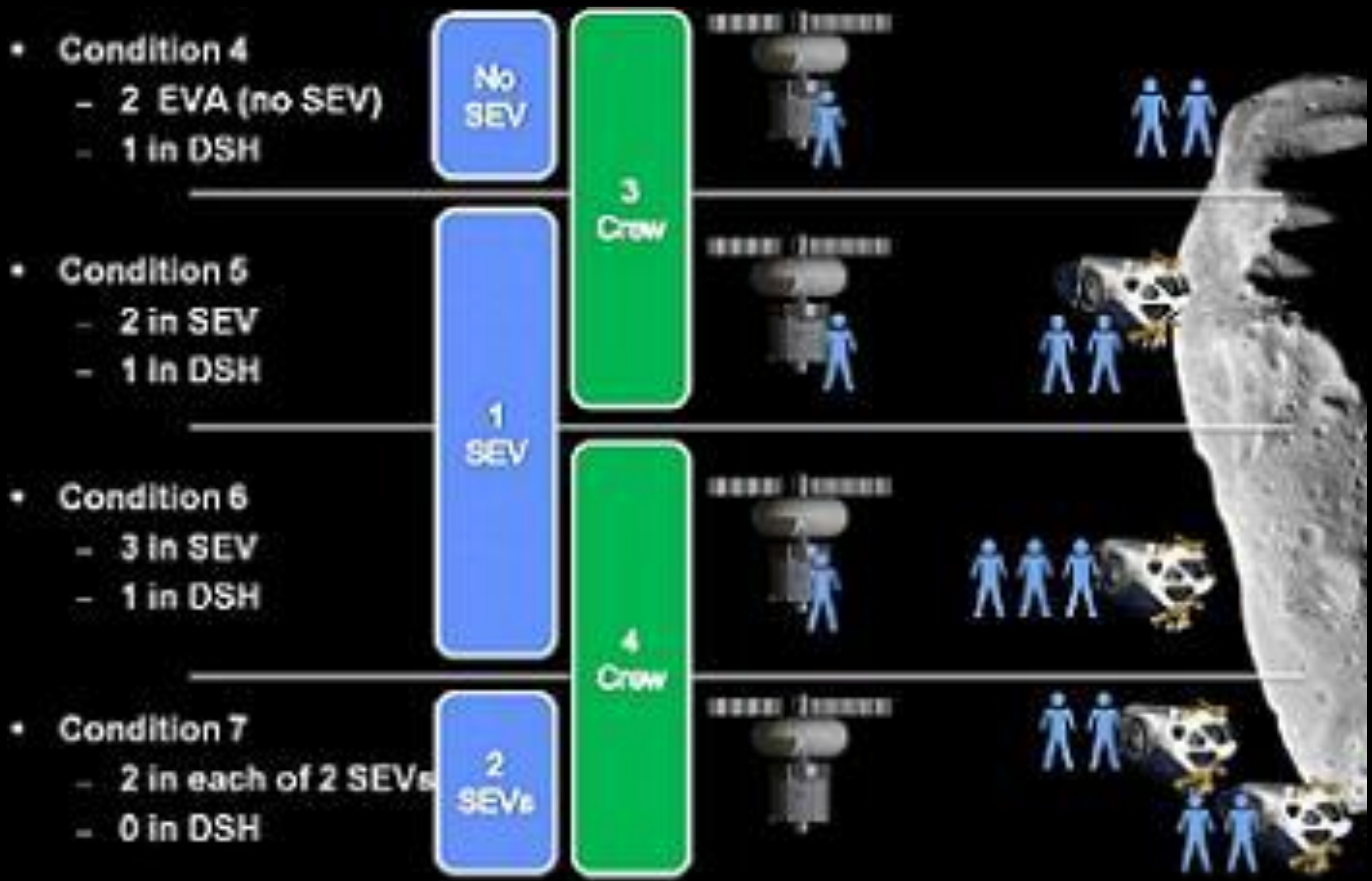
Science Operation Concepts

How will a crew use the various assets to explore the surface? This shows various concepts for how a crew can maneuver around a surface and work together.



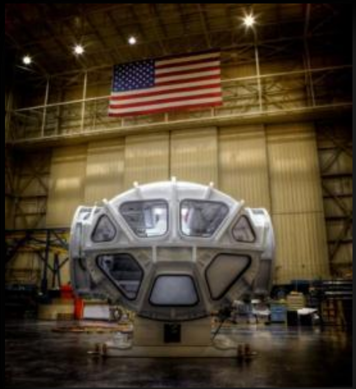
Concepts for Crews & Vehicles

Combinations explored during RATS & NEEMO



RATS Background

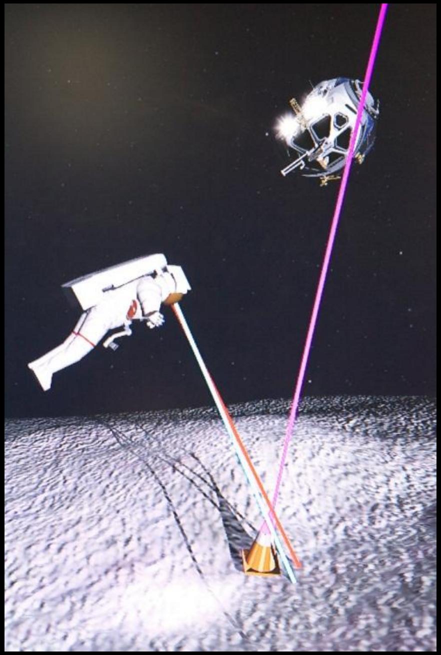
- Desert RATS initiated in 1997 with a 4-member team travelling to Death Valley, California to assess shirtsleeve mobility and field-geology tasks
- Grown to a team of over 100 individuals involved in assessing technologies, mission architectures, and operational concepts in an integrated setting
- All testing through Fall 2011 has been completed in the high desert outside Flagstaff, Arizona
- Currently RATS is in its 15th year of testing
- 2012 is the 1st year of testing to occur solely at JSC



Field Tests for an Asteroid Mission

How do we train for microgravity field work?

- There is no ‘perfect analog’ for NEA surface activities
- Need to integrate and evaluate several mission concepts & EVA training methods
- Each activity offers a different experience applicable to NEA ops
- Training Facilities
  - NEA Flight Simulator
  - Virtual Reality Lab
  - ARGOS
  - MMU/Air Chair
  - MMSEV Air Sled
  - Suit Port Operations



VR Lab

ARGOS

Test Articles, Facilities, & Resources

Elements & Facilities to be tested/exercised:

- **Gen 2A MMSEV** next generation space exploration vehicle mounted to a simulated reaction control system (RCS) sled
- **ABF** (Air Bearing Floor, a.k.a. “flat floor”) smooth, level surface for providing realistic reaction forces for MMSEV/EVA crew translation
- **NEA Simulation** with high-fidelity visuals and integration between MMSEV flight controls and Virtual Reality Laboratory (VR Lab)
- **ARGOS** facility to simulate shirtsleeve microgravity EVAs and exercise NEA translation and science collection tools
- **VR Lab** integrated with the NEA sim to allow virtual EVAs with the SEV around an asteroid
- **MMU/”Air Chair” Trainer** (Manned Maneuvering Unit) integrated with the ABF to simulate reaction forces with NEA during simulated EVA
- **RCS Air Sled** (Reaction Control System) simulated propulsion package for ‘flying’ MMSEV on the ABF
- **EVA Tools** for conducting simulated NEA science collection and EVA translation tasks
- **Mission operations team** providing task timeline planning support
- **Science oversight** ensuring scientific procedural rigor is applied to NEA sample collection techniques

MMSEV Gen 2A Cabin

Inside the MMSEV

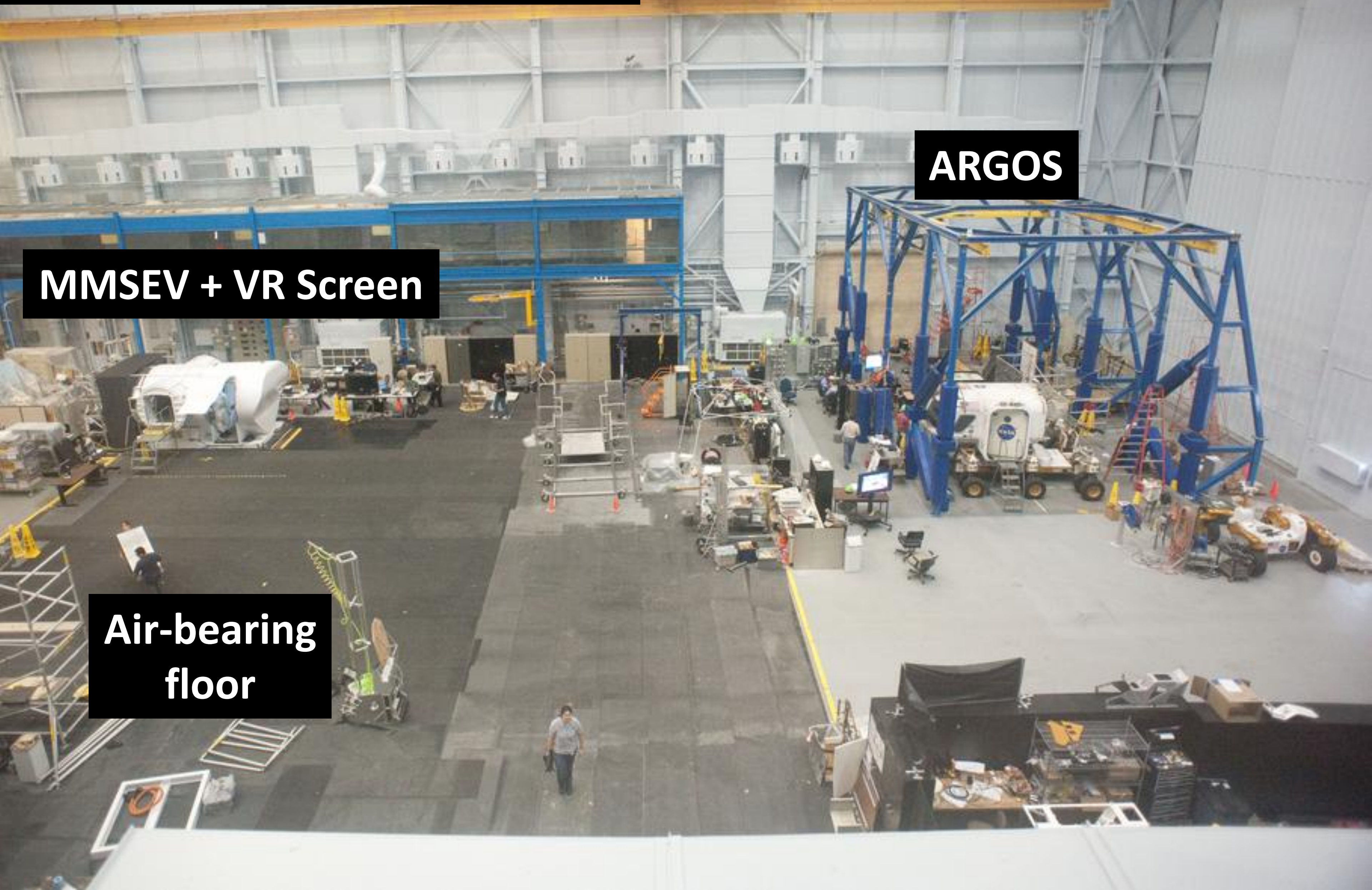
Seats, Displays, & Controls

Starboard Side Hatch

Sleep Station Deployed

Inside Sleep Station

Layout for RATS 2012 inside B9 at NASA JSC

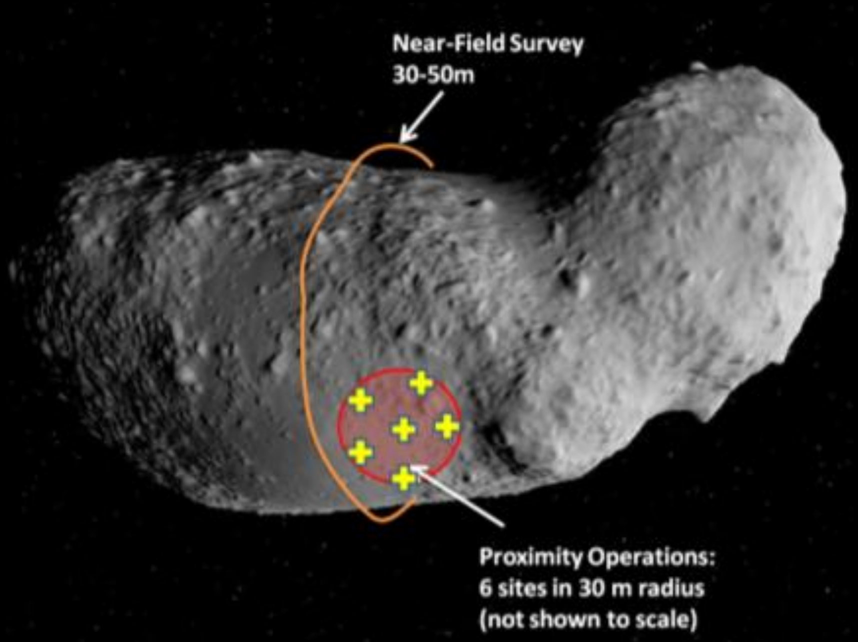


NEA Flight Simulator

- Projection screen in front of MMSEV windows
- Sim uses Asteroid Itokowa
- 'Fly' from inside MMSEV
- Tasks
  - Near-field Survey
    - Fly one orbit around NEA
    - Maintain 30-50 m altitude
  - Focused Inspection
    - Fly MMSEV to each cone
    - Approach to 10 m of cone
    - Proximity for Astronaut Positioning System (APS)
  - Gain estimates of propellant

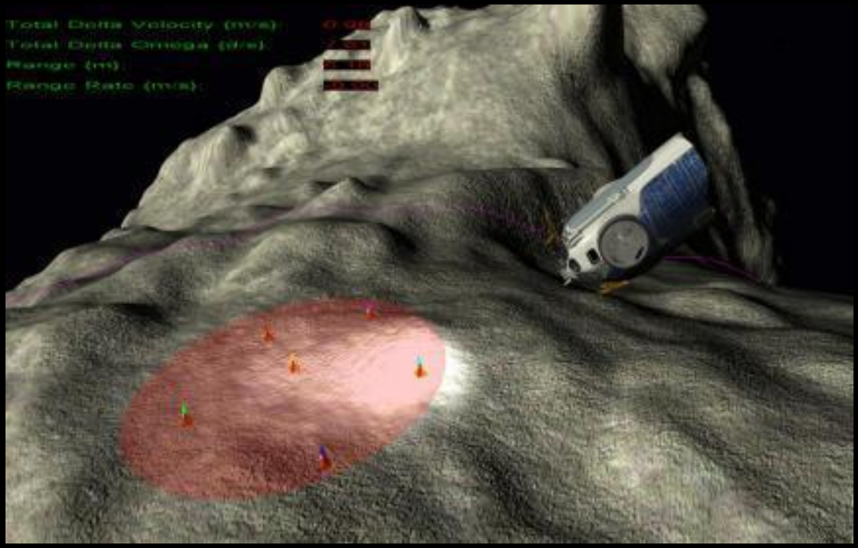
NEA Flight Simulator

Near Field Survey



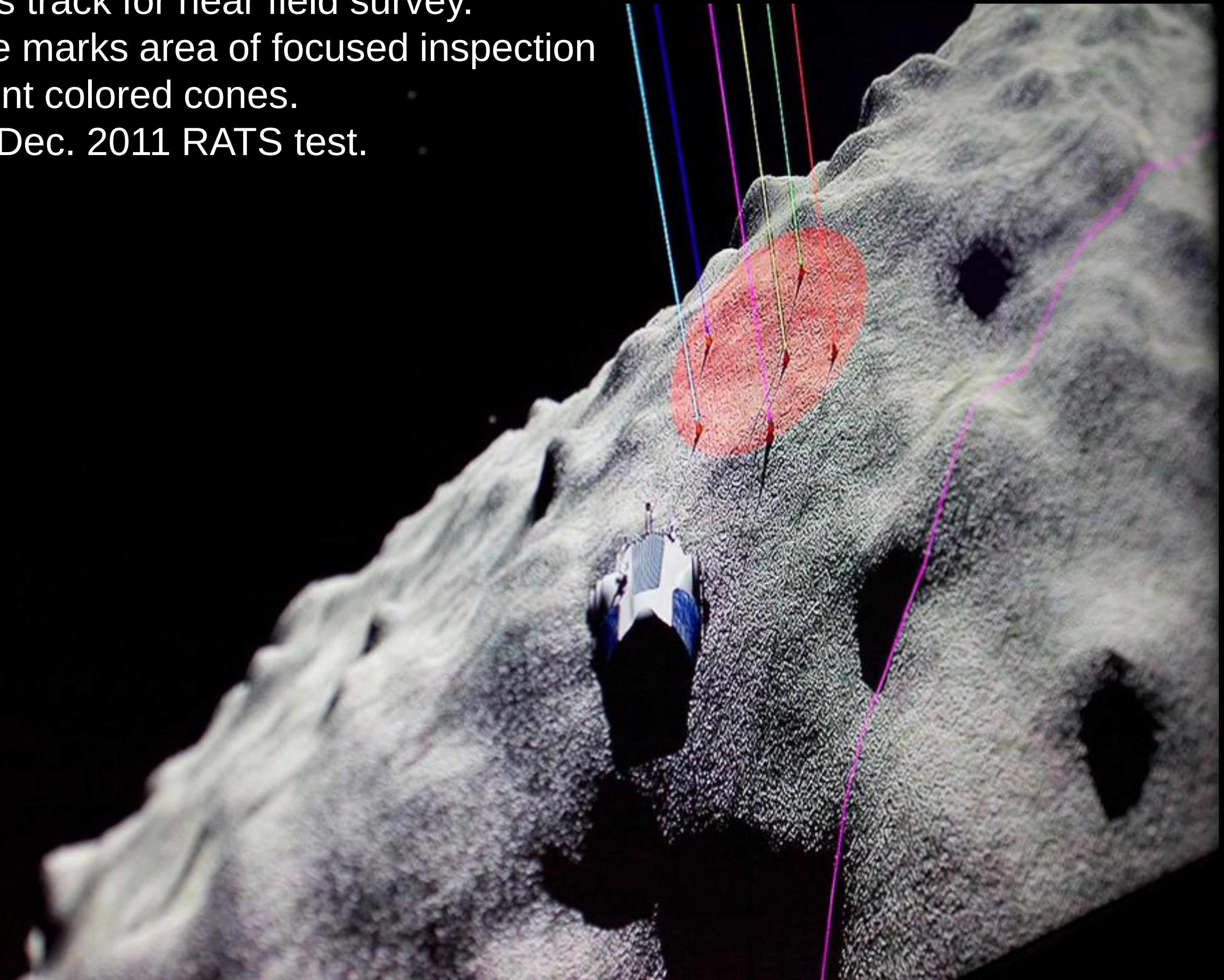
Fly around the asteroid
to survey the surface

Focused Inspection



Precisely maneuver the
MMSEV in a local area

View of MMSEV in the flight simulation.
Pink line is track for near field survey.
Red Circle marks area of focused inspection
of different colored cones.
From the Dec. 2011 RATS test.



Crew inside cabin conducting near field survey of NEA

Virtual Reality Lab

- VR lab used for ISS crews
- Solo EVA ops. on NEA
- 'Fly' using Super SAFER
- Real-time communication with MMSEV
- Colored cones represent points of interest
- Tasks
  - Two EVA operation concepts
    - Cones spaced close together
    - Cones spread out on surface
  - MMSEV provides support
  - Rendezvous with MMSEV

VR Lab setup with SAFER controller

VR Environment

Boulders were added to the asteroid surface to provide realistic features that the crew could observe and explore during the RATS 2012 mission.

Three Person Crew Operation Concept (RATS 2012)

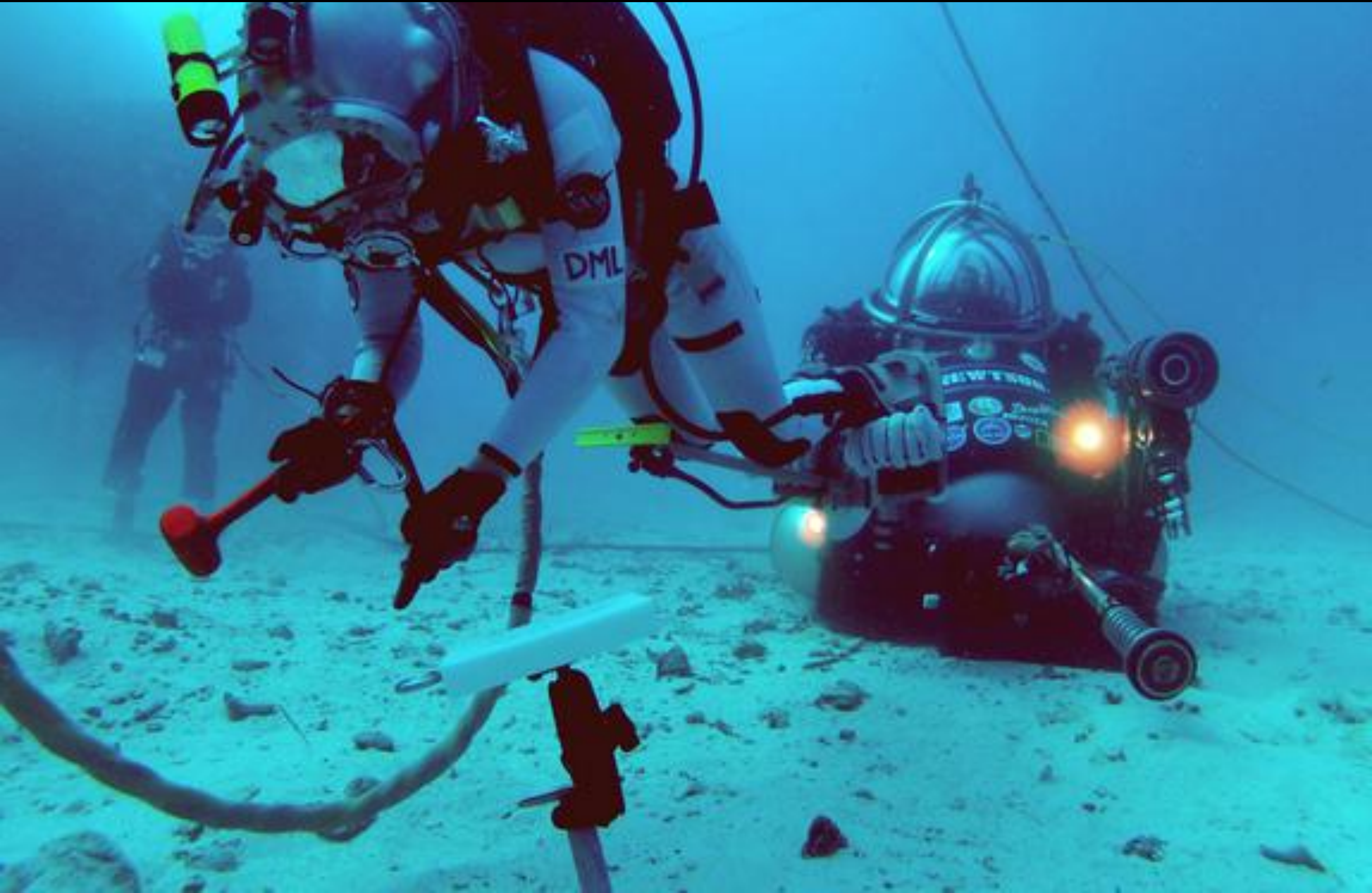
Two crew members stay inside the MMSEV while one crew member is located on the APS. During the tests, the crew member on the APS would be located in the VR lab but could communicate with the crew in the MMSEV.

Two Person Crew Operation Concept (RATS 2012)

One crew member remains inside the MMSEV while one crew member is located on the APS. How different is the workload for the crewmember inside the MMSEV when there isn't another crew member to assist in tasks and station keeping of the vehicle?

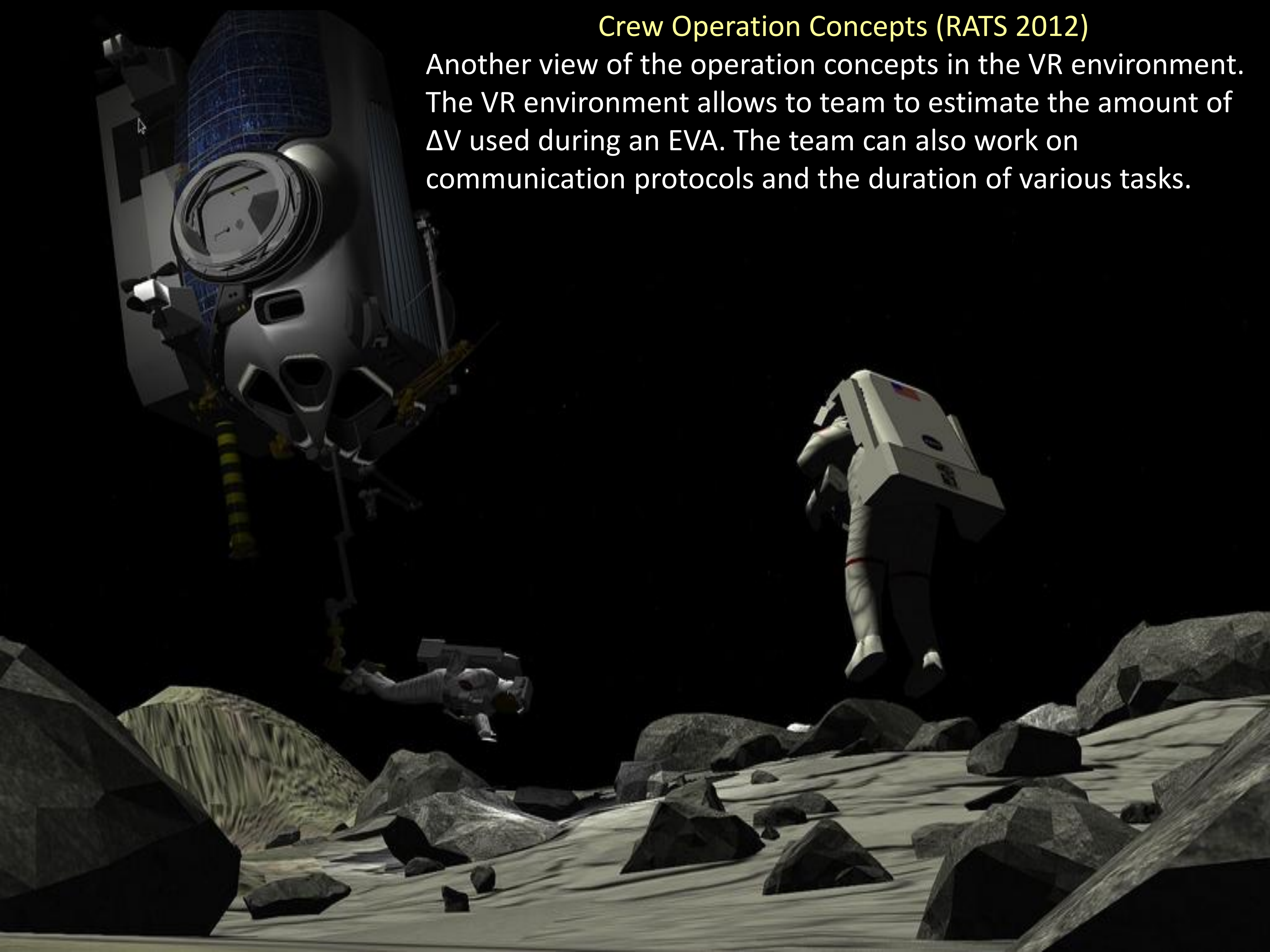
Crew Operation Concepts (NEEMO 16)

Testing the concept of a crew member on the APS attached to an MMSEV (Deep Work Submarine) in the physical environment rather than the virtual environment.

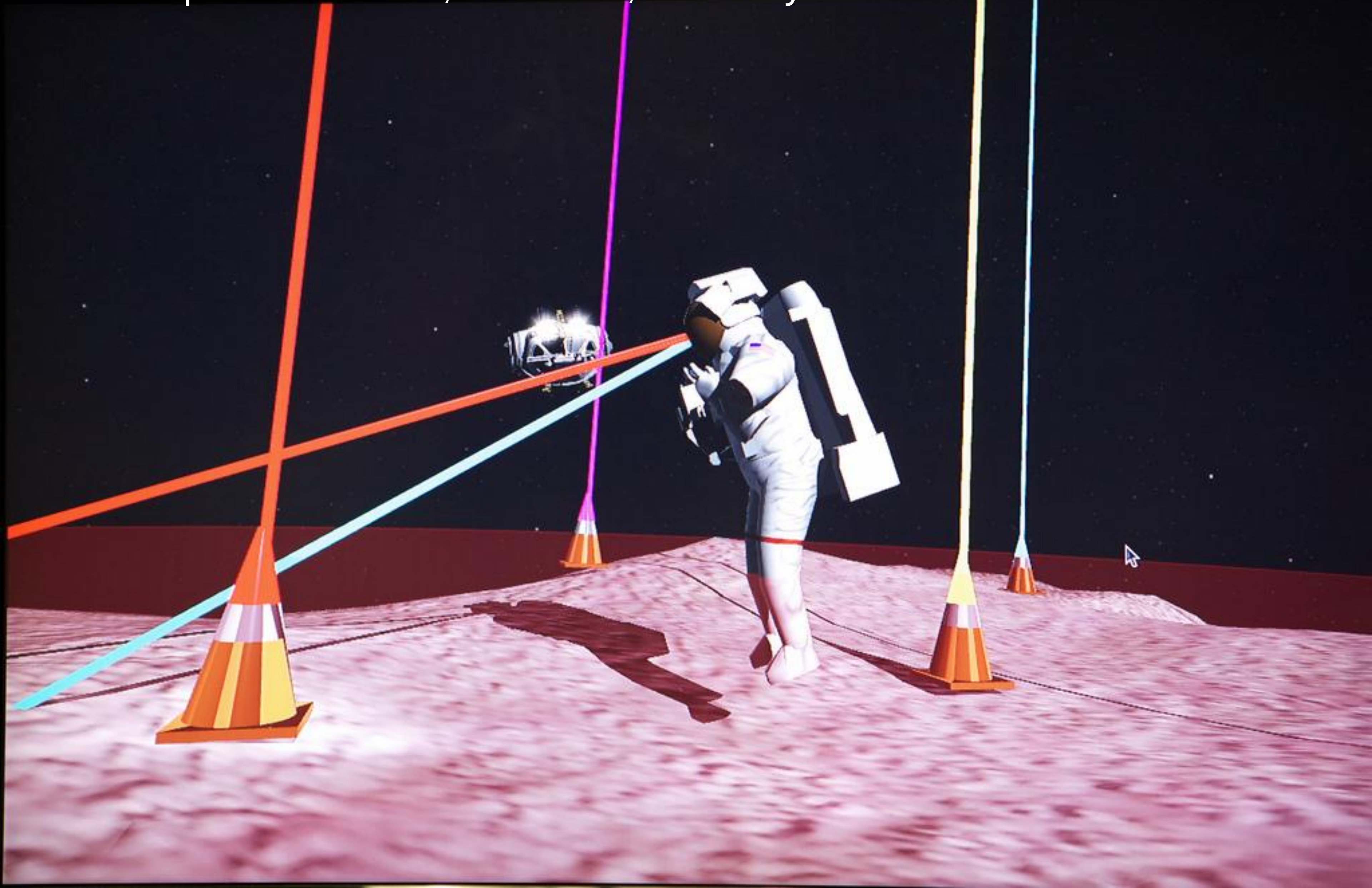


Crew Operation Concepts (RATS 2012)

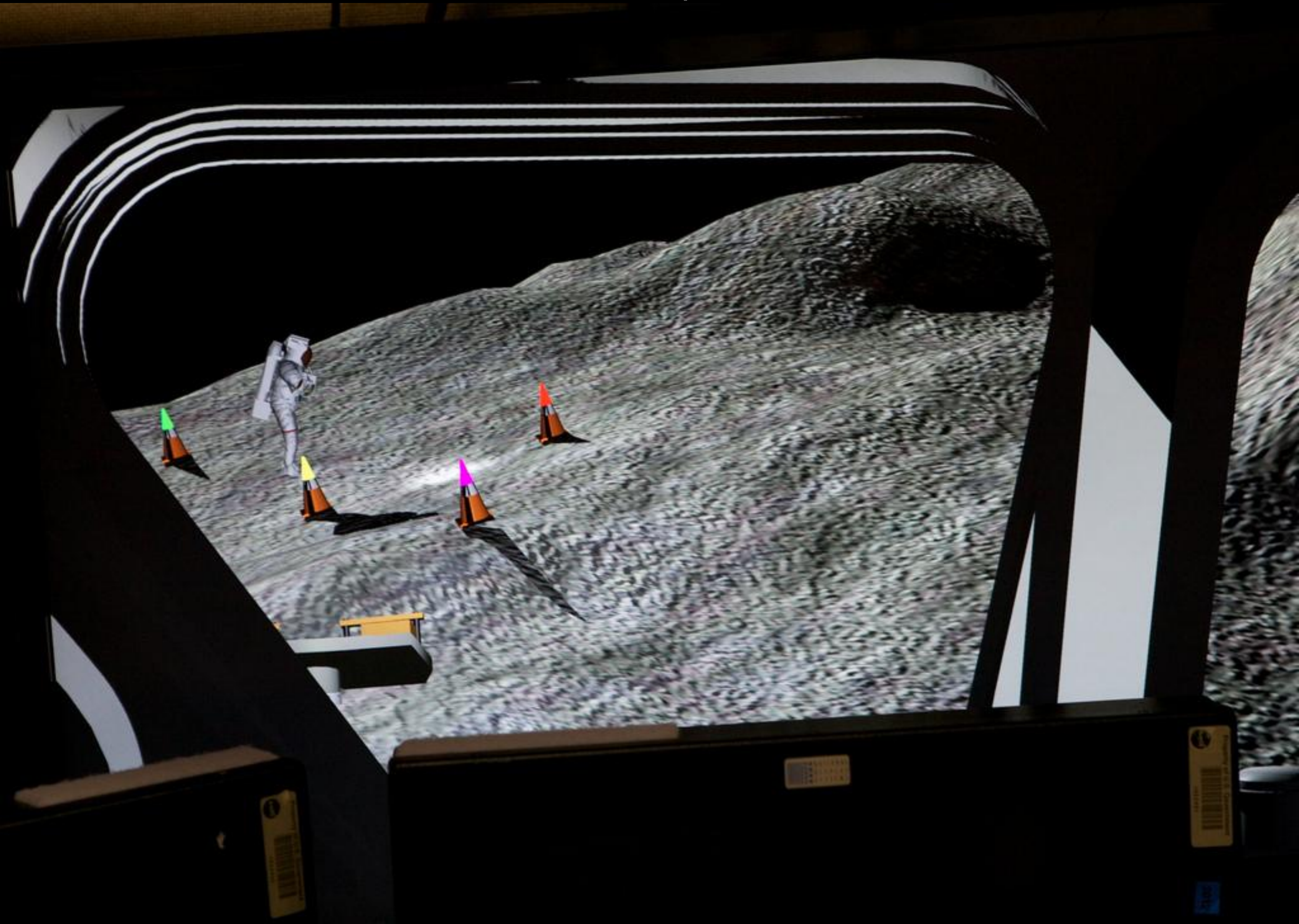
Another view of the operation concepts in the VR environment. The VR environment allows to team to estimate the amount of ΔV used during an EVA. The team can also work on communication protocols and the duration of various tasks.



View of integrated VR Simulation with MMSEV and Crew Member on EVA using the Super SAFER (jetpack) concept (RATS Dec. 2011). The MMSEV can provide context, directions, and body orientation to crew on EVA.



View of VR simulation out MMSEV cockpit windows of crew member on EVA



DSH

Deep Space Habitat

Crew Operation Concepts (RATS 2012)

Two crew stay in the DSH to work with two crew that are in the MMSEV or on EVA.

ARGOS EVA Operations

Active Response Gravity Offload System

- Two operation modes
  - Vertical harness
  - Horizontal harness
    - fewer degrees of freedom
- Real-time communication with MMSEV
- Tasks
  - Translation Tools
    - Translation lines
    - Telescoping pole/boom
  - Geologic Sampling
    - Float & Regolith
    - Hammering tool concepts
  - Deploy Instruments/Sensors

ARGOS Horizontal Harness

Translation Concepts. This shows the concept of using multiple lines extending from a central anchor point used for translation across the surface. ARGOS offsets the weight of the crew to simulate aspects of microgravity (RATS Dec. 2011)

Sampling Techniques: Crew tethered to a translation line, preparing to collect a regolith sample. What tools need to be designed for geology in microgravity?

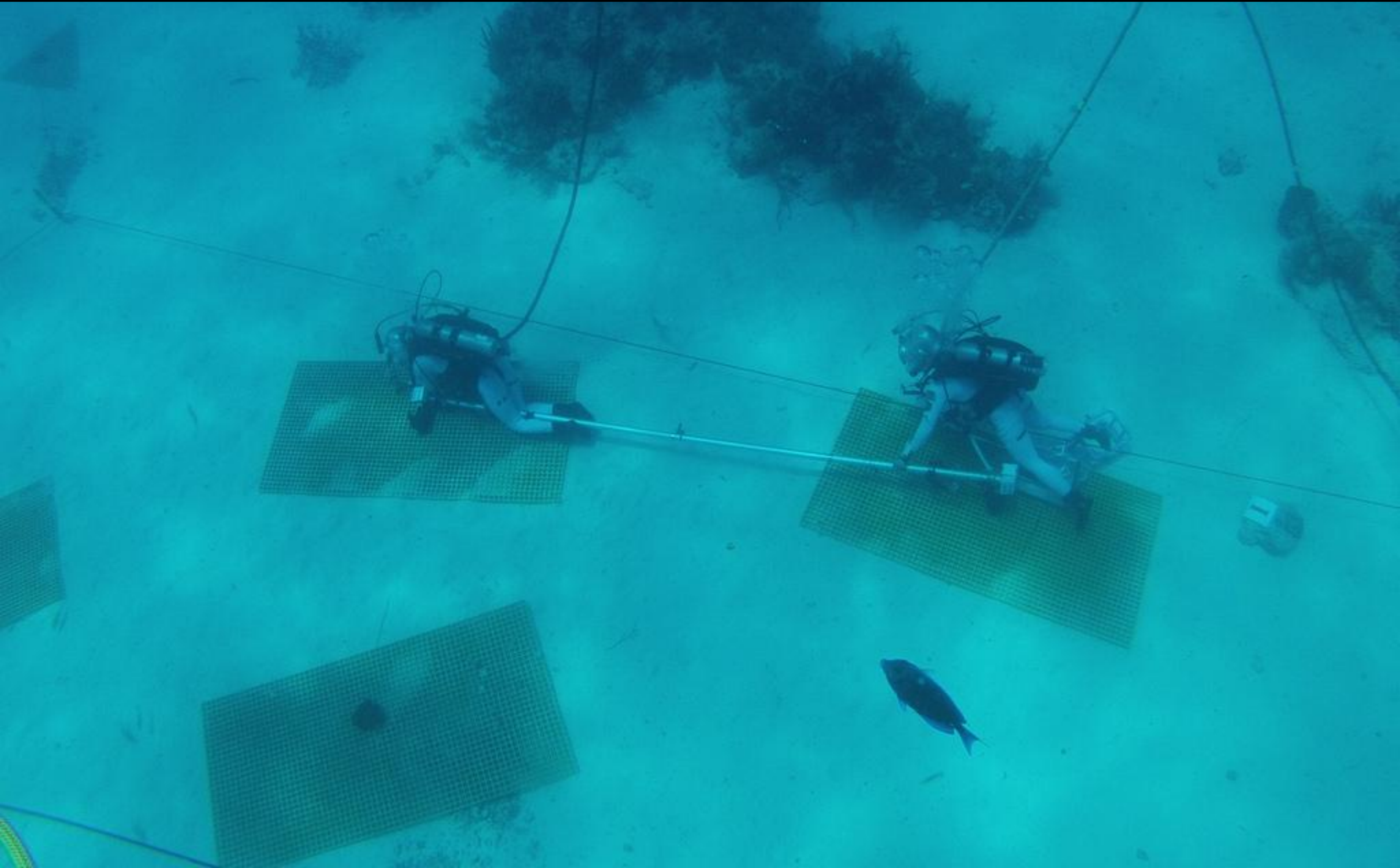
Deployment of sensors using the Boom

Rock Chip Sampling

Boulder Sample

Translation Concepts (NEEMO 16)

Crew members on NEEMO 16 practicing anchoring and translating along the ‘Boom’ to the ‘surface of the asteroid’. A stable, telescoping pole that can be anchored on either end is one concept being tested for maneuvering across the asteroid surface.



ARGOS sampling circuit (RATS 2012)

Various materials were used for sampling by crew from boulders, pebbles, rubber, and cork.

Crew would begin EVAs from the aft deck of one of the Gen 1 versions of the MMSEV.

ARGOS sampling circuit (RATS 2012)

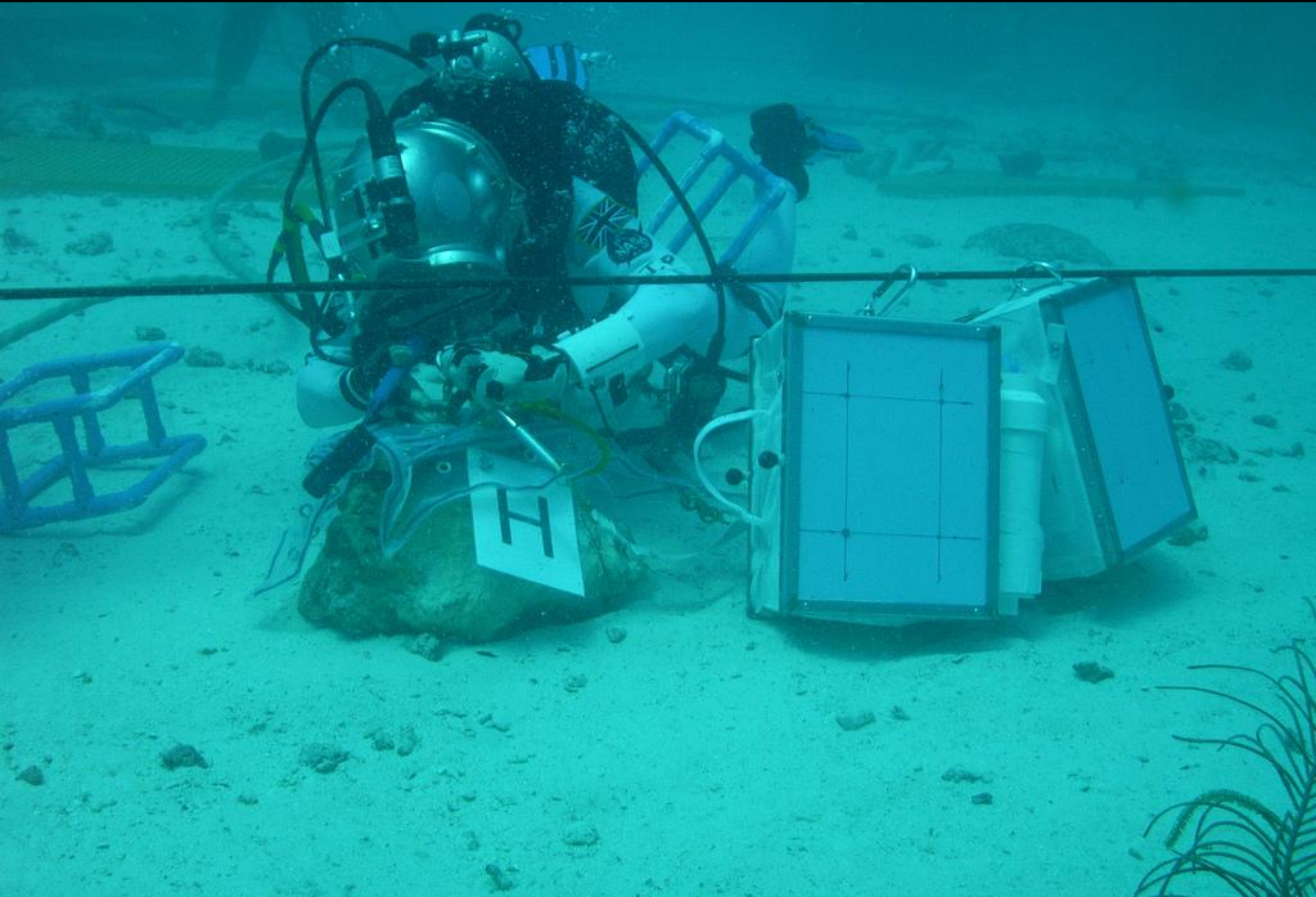
Crew member attempts to hammer a core tube into a 'regolith'. How will traditional geology techniques and tools need to be modified for the microgravity environment?

ARGOS sampling circuit (RATS 2012)

Crew practices collecting a hard rock sample. A blanket with built in chisels is laid over the rocks. The blanket protects the crew from flying shrapnel and traps the chips for collection.

NEEMO sampling circuit (NEEMO 16)

This same sampling concept for boulders was tested underwater.



MMU/ “Air Chair” Trainer

- Manned Maneuvering Unit (MMU) used on Air Bearing Floor (ABF)
- 3 Degrees of Freedom
  - (Forward/Back, Left/Right, Yaw)
- Tasks
  - Geologic sampling
  - Deploy translation lines
  - Tethered vs. un-tethered
  - Rockwall proximity ops.

Translation along a Tether

Free Flying the Air Chair

MMSEV RCS Air Sled Integration

- Reaction Control System (RCS) air sled
- 'Fly' MMSEV on the Air Bearing Floor (ABF)
- 3 Degrees of Freedom
  - (fwd/back, Lft/Rgt, Yaw)
- Tasks
  - Close approach
  - Simulated docking
  - Evaluate windows

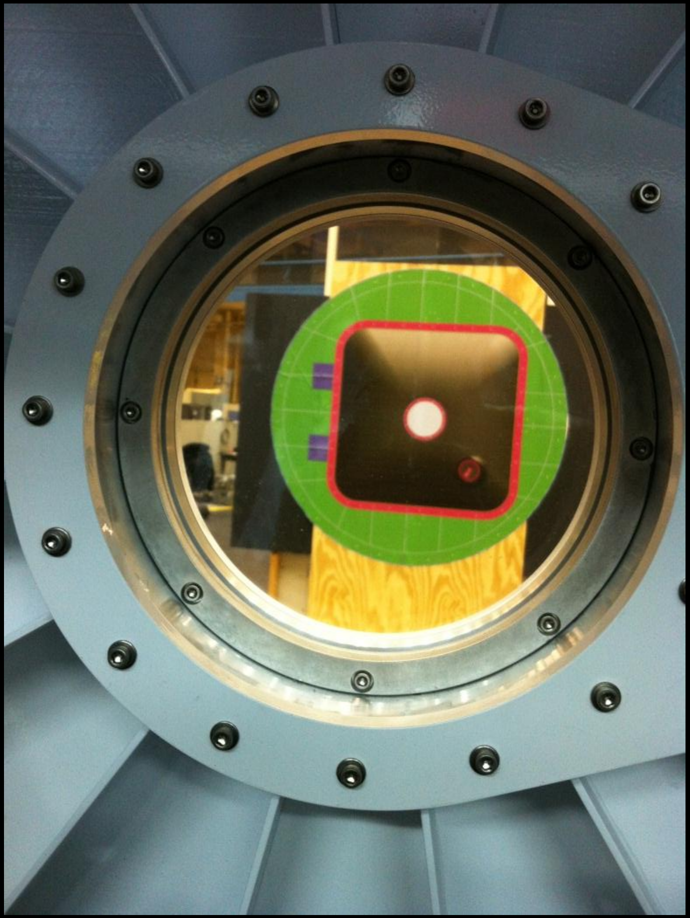
Air Thrusters

MMSEV docking operations on the Air Bearing Floor (ABF)

MMSEV docking operations on the ABF

Closing the gap on the docking target

View from side hatch window



MMSEV docking operations on the ABF

Mark III Mock-Up Suit Port

- Rear-entry suit port
- 15 minutes for ingress & egress
- Lowered control panel
- Upgraded interface
- Tasks
  - Conduct suit port ops for each EVA
  - Evaluate Gen. 2A interface & controls

Training Elements to Consider for Field Work at an Asteroid

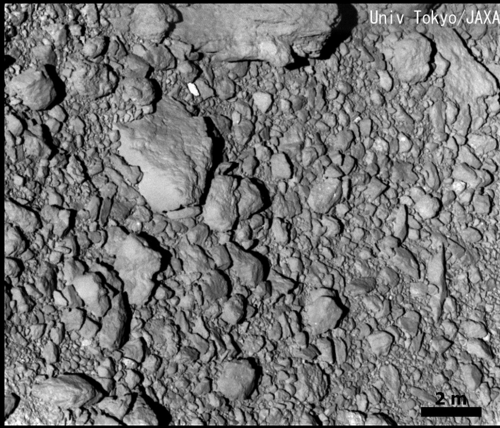
- Scale of the Asteroid: Use asteroids with various dimensions (10-100 m) representative of an NEA mission in the VR flight simulator to give appropriate spatial and visual scale.

- EVA tasks: Design EVA activities/circuits so that the current EVA tasks build on prior EVA tasks and equipment deployment during the integrated test to get an idea of the overhead logistics and time it takes to translate across the surface.

- Science observations: If possible, the crew needs to work in an environment that allows them to make real-time decisions, make realistic observations and collect samples with a purpose.

- Future work: Test EVA activities in a pressure suit in NBL and ARGOS (translation methods, sampling techniques). Tool designs may be different to accommodate for use in a pressure suite.

Questions for Field Geology



- What instruments & tools are necessary?
  - Traditional field tools (hammer, sample bags)
  - Handheld instruments
  - How do they need to be modified for microgravity?
- How will the crew explore the surface?
  - EVA (Super SAFER, MMSEV + APS)
  - Autonomous Robotics and/or Telerobotics
- How will surface characteristics determine operation concepts?
  - Smooth, small craters, featureless
  - Blocky, boulders, unstable
  - How easy will it be to anchor into the surface?
- What terrestrial analogs can be used for field training?
  - DRATS 2011 at Black Point Lava Flow, AZ
  - NEEMO 15 & 16 at Aquarius, Key Largo, FL

Crew Operation Concepts (Desert RATS 2011

Various operation concepts were tested during the DRATS 2011 field test at Black Point Lava Flow. While the 1g environment is not analogous, the crew was able to work on communication protocols, sampling techniques, as well as explore geologically relevant features.

Summary

- ***Analog field tests are critical for understanding how to operate in planetary environments!*** Multiple training facilities and environments need to be used to help simulate various aspects of microgravity while exploring an asteroid. Both VR and physical environments serve a training purpose.

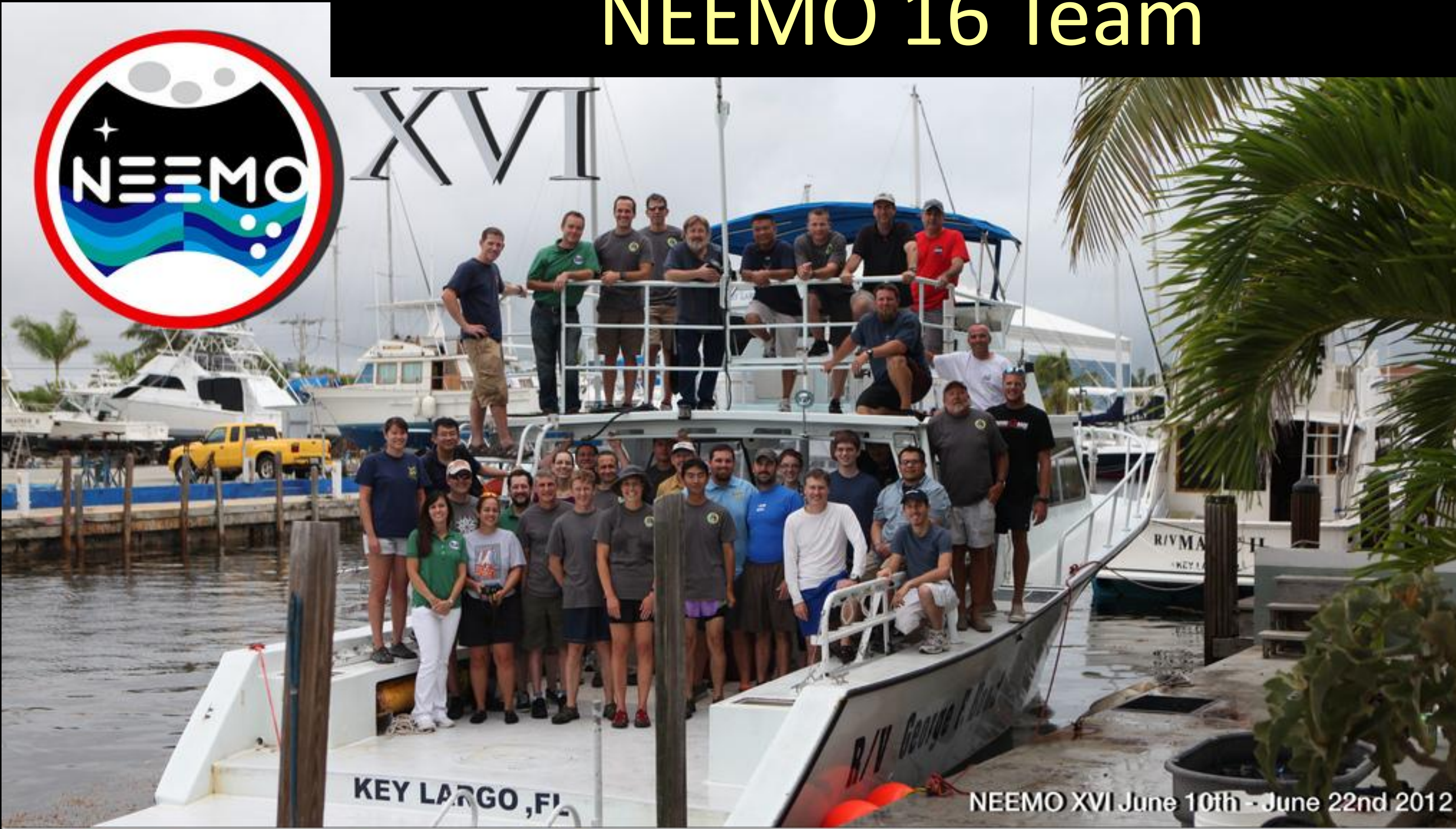
- ***We need to build on our experiences with Apollo, Shuttle, and ISS, but not be complacent!*** Training for NEA exploration builds on the foundation of both LEO and lunar surface operations, but modifications must be made for the unique environment of asteroids, including the geology tools that will be used.

- ***Design! Build! TEST! Repeat!*** Vehicles, operation concepts, and equipment need to be tested within an integrated mission simulation to drive new designs, concepts, and mission protocols for NEA exploration.

- ***Planning ahead!*** Reconnaissance of Asteroids will be important for field geology planning. Combinations of techniques discussed here may be used depending on surface properties and size of the asteroid.

RATS 2012 Team

NEEMO 16 Team



RATS Websites and Social Media

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